CHAPTER IV
RESULT

In the previous experiment (1), the results showed that the color appearance of the test patch returned suddenly to the original color when the window was changed from W2 to W3. So in this experiment we are interested to know whether the color of an objects would return to their original color, or the color constancy would take place for objects when apply to a reversed situation of room illumination from that employed in that previous experiment.

The color appearance of the test patch was determined by subjects. Each determination was not difficult for them. They could easily judge color appearance of the test patch by using elementary color naming method and took only a few minutes at the longest for experienced subjects and a little longer for inexperienced subjects. The color of the test patch appeared natural as an object in the space in most cases, but with a few exceptions. With the combination of red light 19 lx with daylight 6 lx and with window1 and 2 the red (5R5/3), yellow (5Y5/3) and gray (N5) test patches appeared unnatural. Including the extreme condition that was only red illumination 25 lx also observed such unnatural. They appeared too bright as an object in the subject room or sometime appeared shining. Yuwadee et al. (8) used the words unnatural object color and light source color for these appearance. But with all intensities of yellow illumination such unnatural appearance was not experienced at all. According to the concept of RVSI an object looks unnatural if it has the luminance to locate outside the RVSI.

4.1 Results of control experiments

The results of the control experiment are shown by using a usual color appearance diagram of hue and chromaticness elements. The chromaticness is given by the distance from the center and the outermost corresponds to the chromaticness of 100%. The coordinate gives the hue in terms of the percentage of the unique hues, R, Y,

G and B. The color appearance of illumination of the test room (appendix A) is shown in Fig. 4-1a for red illumination and Fig. 4-1b for yellow illumination for all subjects. The appearance was judged by looking at a gray patch N5 placed in the test room through the window 1. Different symbols represent subjects, circle for the subject PP, X for DH, diamond for JJ, triangle for PH and square for MW. A filled circle shows their average. The color of the red condition R5+W20 appears almost the unique red. The other three conditions individual variation is large in judging the color of illumination. Although the data points vary among subjects in the case of red illumination, the average indicates that the appearance of test room illumination is almost unique red. In the case of yellow illumination, the color appearance of test room illumination happened to be almost unique hue. Variation of data points is not large as in the case of red illumination, the appearance of the test room illumination is judged as unique yellow.

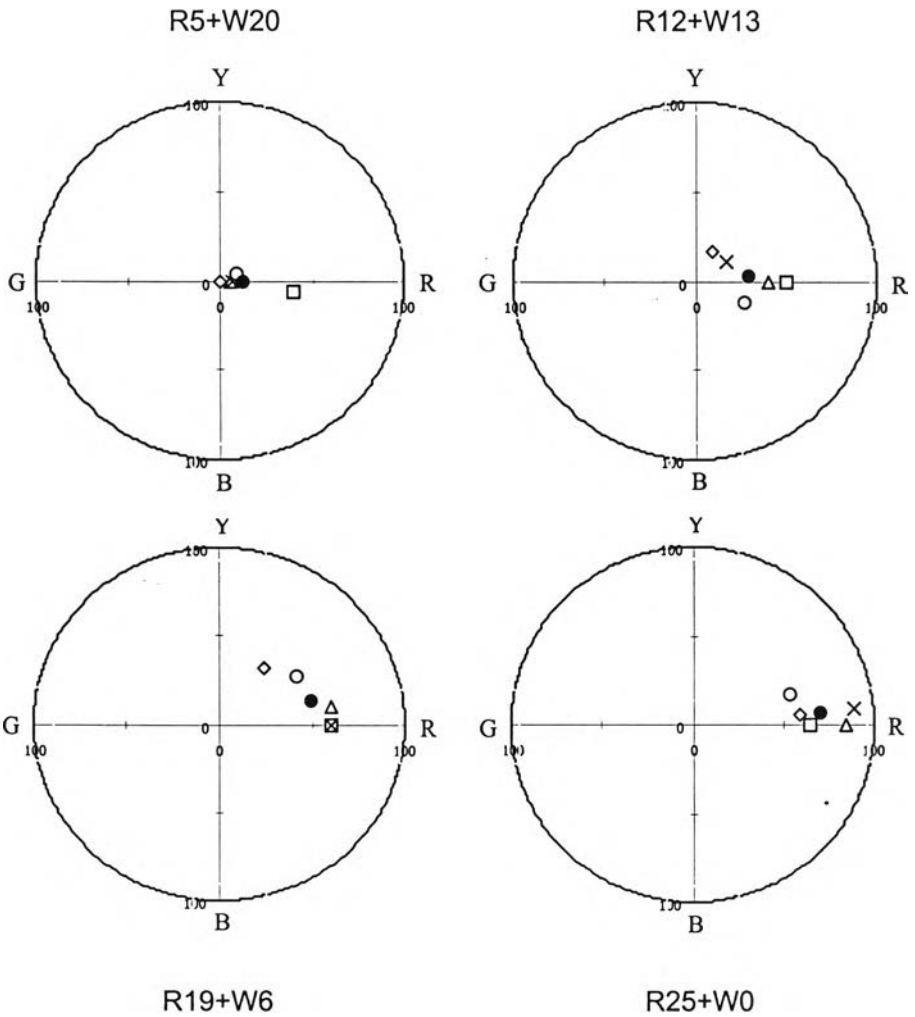

Fig. 4-1a Colors of four defined saturations of red illumination as judged for the test room. ○ , the subject PP; X , DH; ◇, JJ; △, PH; □, MW; ● , the average.

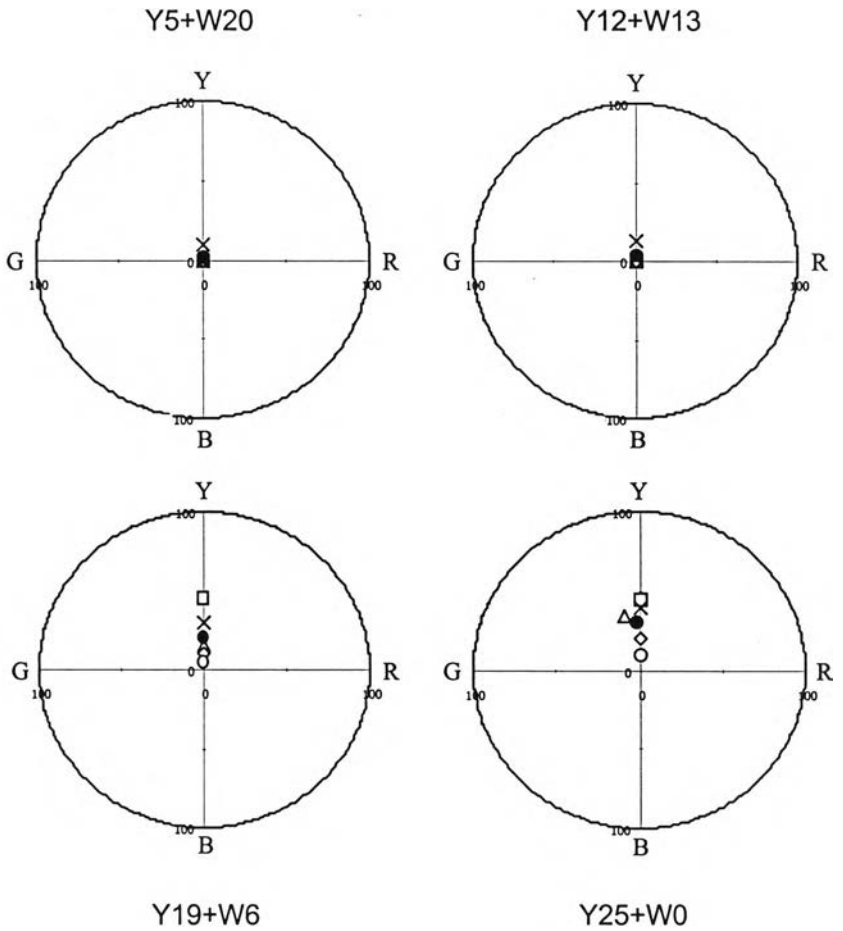

Fig. 4-1b Colors of four defined saturations of yellow illumination as judged for the test room. ○, the subject PP; X, DH; ◇, JJ; △, PH; □, MW; ●, the average.

The original color of the test patches (appendix B) are shown in Fig. 4-2 for all subjects. These were obtained by observing test patches through the window 5 for room illumination of daylight type for both subject and test rooms. Different symbols represent subjects and their average as before. The color of the test patches were close to the unique hues. Individual variation is large in judging the color of the test patches because their colors were judged as an attribute of an object.

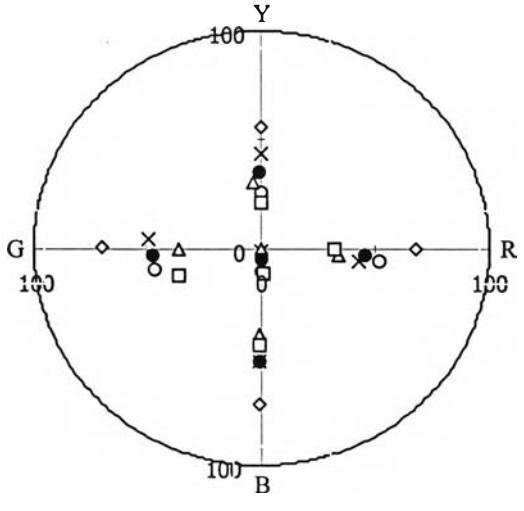

Fig. 4-2 Original color as judged for the test patches.

4.2 Results of main experiments

Results of the judgment by five subjects (appendix C) are shown in Fig. 4-3a for the test patch 5G5/3 with the red illumination R5+W20 condition and in Fig. 4-3b for the test patch 5B5/3 with the yellow illumination Y12+W13 condition. Each section corresponds to a subject. Different symbols indicate the five sessions, squares for session 1, triangles for session 2, diamonds for session 3, X for session 4 and circles for session 5. Their averages are shown in Fig. 4-4a and b, respectively. The color appearance of the test patch 5G5/3 (in Fig. 4-4a) and 5B5/3 (in Fig. 4-4b), seen through window of various sizes, is shown by open circle. The color appearance of the test room is shown by a filled square and of original color of the test patch by X.

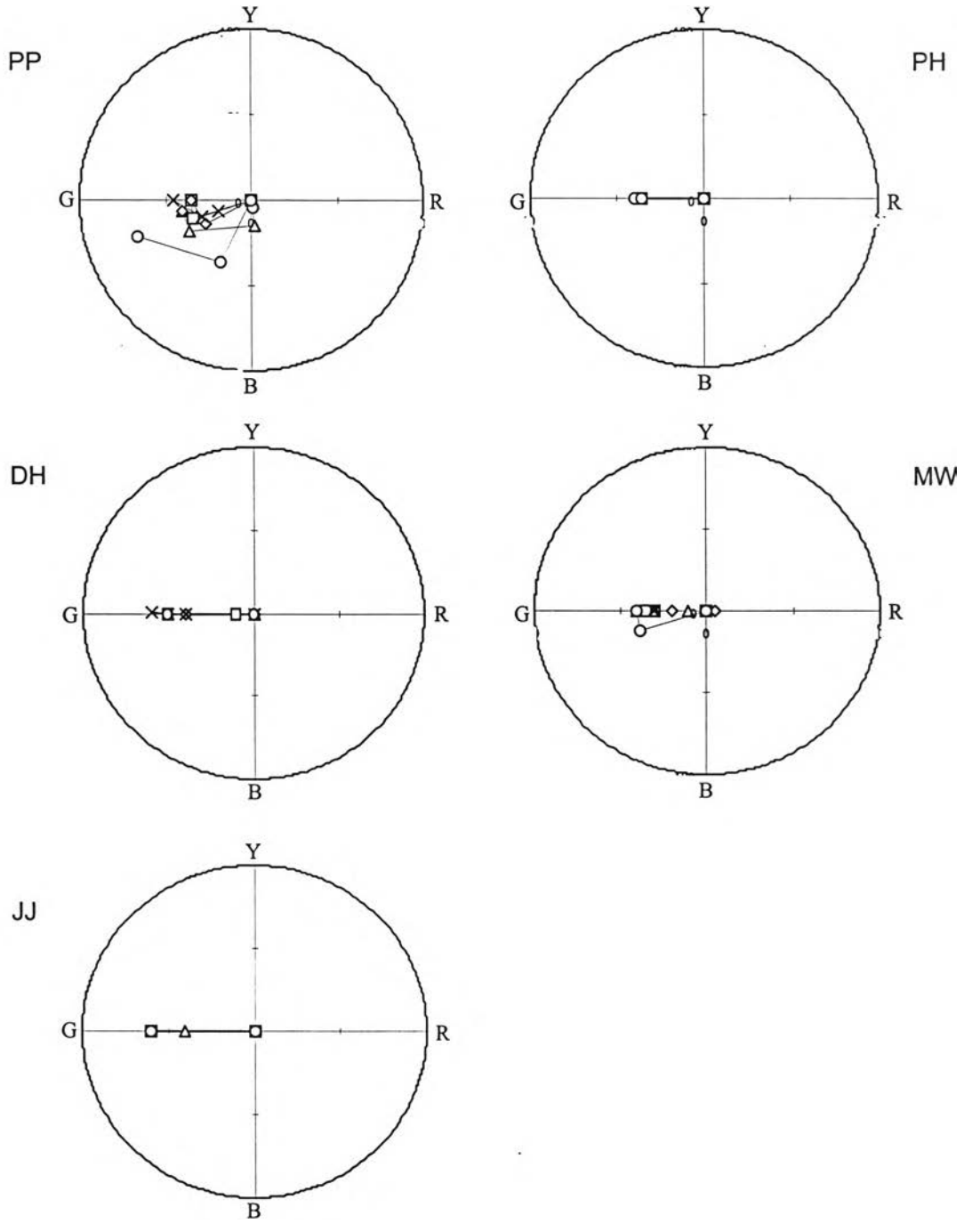

Fig. 4-3a Data from the red illumination R5+W20 and green test patch 5G5/3 combination plotted for five sessions. Sections correspond to subjects.

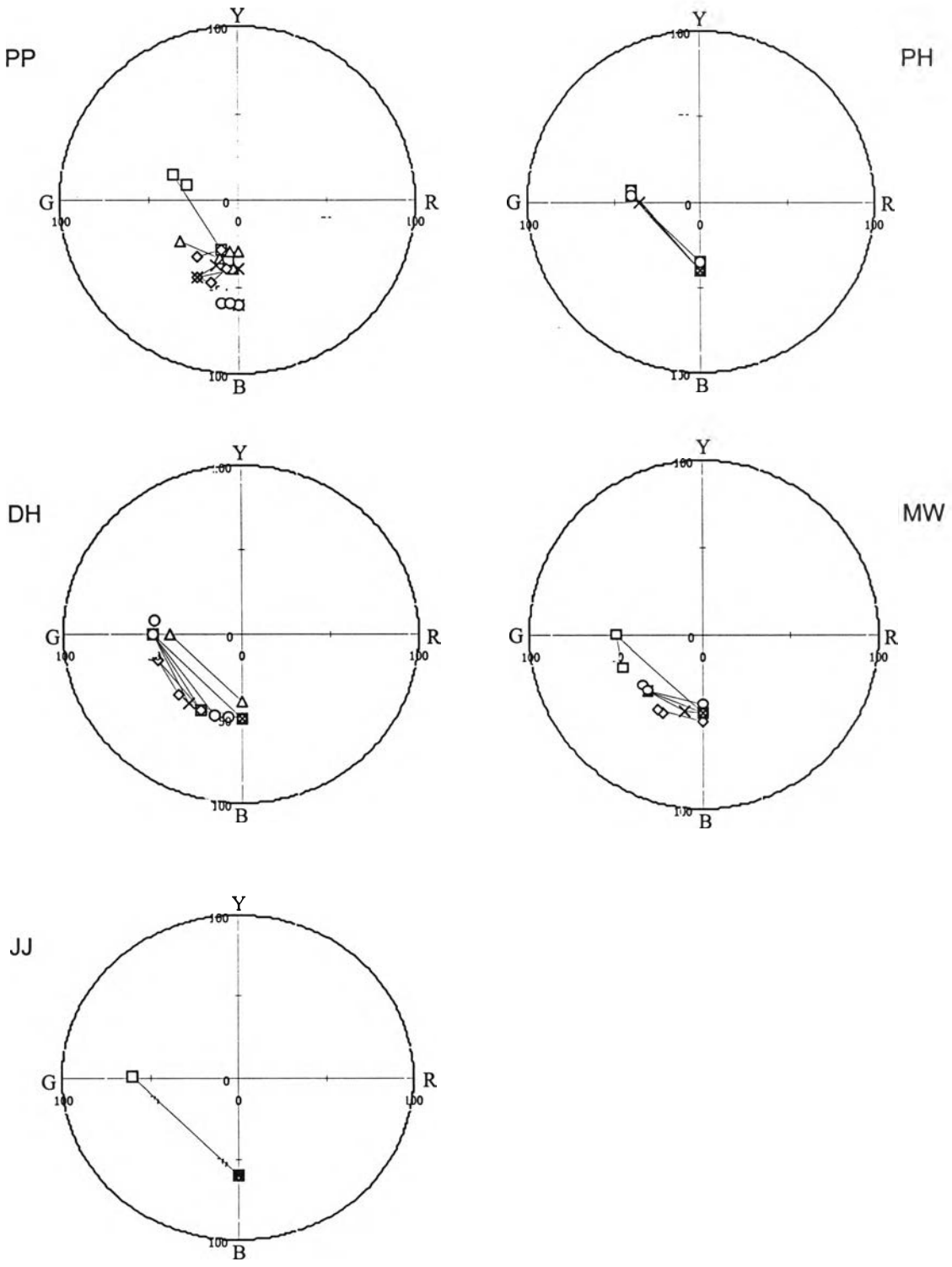

Fig. 4-3b Data from the yellow illumination Y12+W13 and green test patch 5B5/3 combination plotted for five sessions. Sections correspond to subjects.

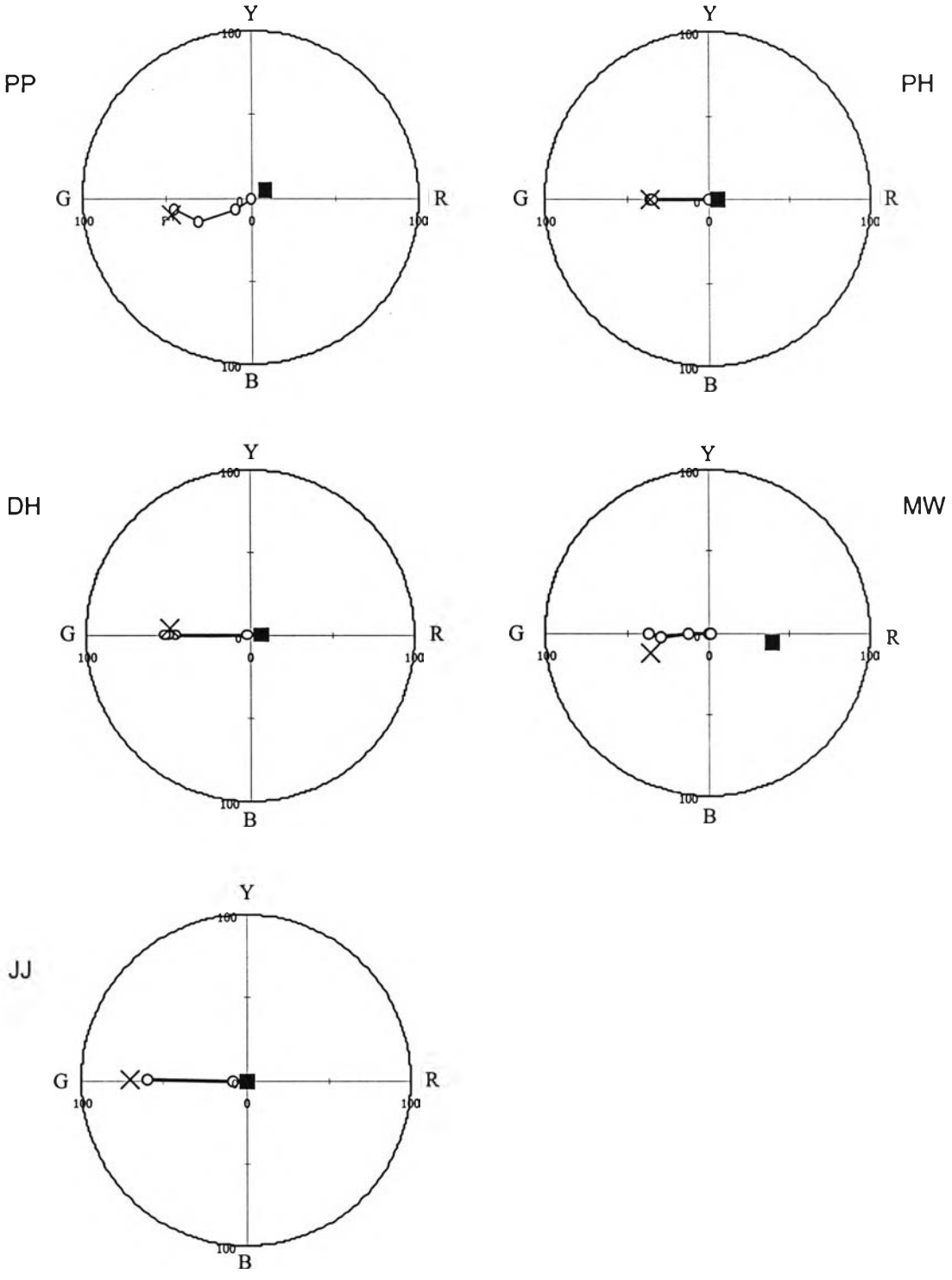

Fig. 4-4a Data from the red illumination R5+W20 and green test patch 5G5/3 combination plotted for average

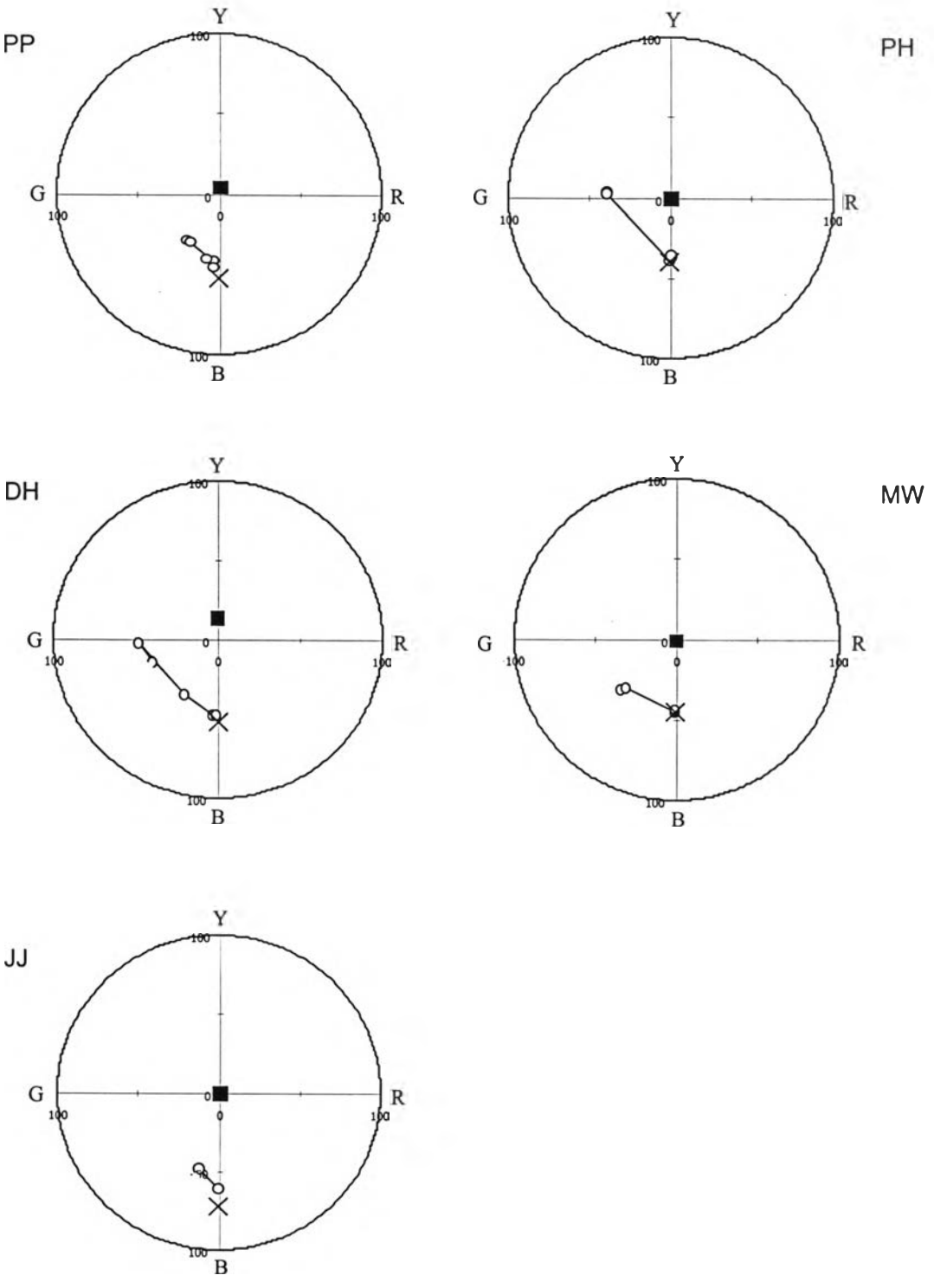

Fig. 4-4b Data from the yellow illumination Y12+W13 and blue test patch 5B5/3 combination plotted for average

There are always a set of five data points corresponding to five different windows W1, W2, W3, W4 and W5, but some points overlap and we can only see fewer points. In Fig. 4-4a when the test room illumination was red, the data points from W1 and W2 overlap in all subjects and they locate at the rightmost point in all the subjects. In most subjects it locates at a bit left side of but very close to the illumination color. The interpretation of the color appearance for these conditions is simple. The test patch is seen as an object placed in the subject room as it fills the window completely and appears as if it is pasted on the front wall of the subject room. The color appearance is therefore determined in relation to the recognition axis of the RVSI constructed for the subject room. As the subject room is illuminated by a white light, the direction of RX coincides with that of the fundamental axis FX or the vertical direction in the illustration of RVSI. The color appearance then coincides with the psychophysical color that is the color suggested by the chromaticity coordinates.

Figure 4-5 shows the chromaticity coordinates of five test patches measured under the test room illumination of red (R5+W20) and yellow (Y12+W13). The measurements were actually done by increasing intensity of lamps by keeping the ratio of colored lamp and white lamp to make the luminance of the test patches high enough to be measured by a color luminometer. Filled square and circle show the chromaticity coordinates of red and yellow illumination, respectively. Open squares are chromaticity coordinates of test patches under the red illumination and open circles under yellow illumination. The open square with a dot inside indicates the test patch 5G5/3 of Fig. 4-4a and the open circle with a dot inside indicates the test patch 5B5/3 of Fig. 4-4b. A cross shows the chromaticity coordinates of the white lamp used in the test room.

In Fig. 4-5 we see that the green test patch locates toward upper left from the red illumination color that is toward green direction. This is reflected in the results shown in Fig. 4-4a when the window was small, W1 and W2. In Fig. 4-5 we see that the blue test patch locates toward left from the yellow illumination color that is toward greenish blue direction. This is also reflected in the results shown in Fig. 4-4b with W1 and W2.

In Fig. 4-4a it is clear that when the window was opened to W3 the color appearance suddenly shifted toward left and came close to the original color. That sudden change with W3 did not take place in the subjects PP and MW, but the shift toward left occurred. The sudden change shows that the color constancy took place with W3. This fact was found by Pontawee et al. (1) and they concluded that as soon as subjects recognized the existence of the test room the RVSI for the test room was constructed and the color appearance of test patches was determined based on the RVSI. This is nothing but to say that the color constancy took place. The sudden recovery to the original color is also confirmed in Fig. 4-4b.

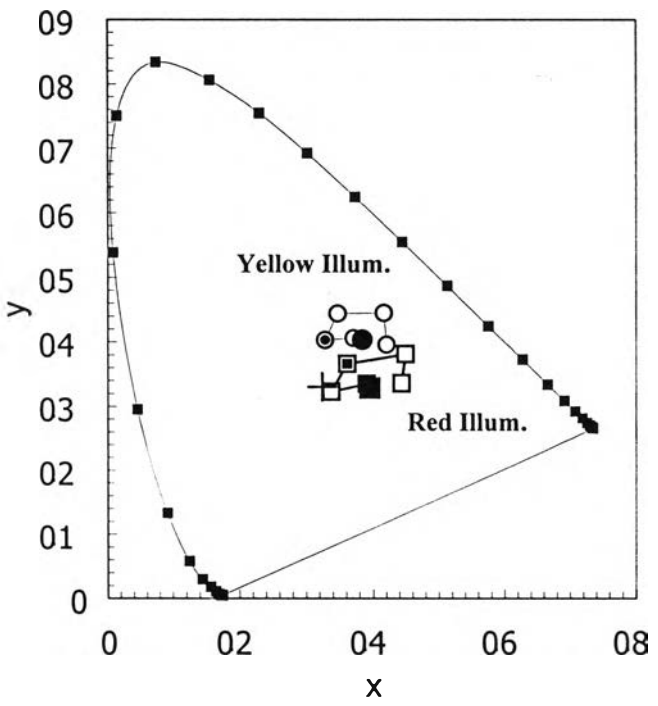

Fig. 4-5 The chromaticity coordinates of five test patches measured under the test room illumination of red (R5+W20) and yellow (Y12+W13)

The results from all five subjects and for all the saturations of red illumination (appendix C) are shown in Fig. 4-6a-d, a for R5+W20, b for R12+W13, c for R19+W6 and d for R25+W0. Sections in each figure corresponds to subject as in the case of Fig. 4-4. Different symbols represent test patches, square for 5R5/3, triangles for 5Y5/3, diamonds for 5G5/3, exes for 5B5/3 and circles for N5. Filled circles show the original color of the test patches and large filled squares show the colors of illumination.

When the window was small as W1 and W2 the color appearance of the test patches shifted to the red direction but in different degrees depending on the saturation of red light. In these situations the color of the test patch was judged based on the RVSI of the subject room and the color appeared as expected from psychophysical color of the test patches. When the window was enlarged the color shifted to return to their original colors because the color of the test patch was judged based on the RVSI of the test room. For the condition R5+W20 the color appearance of the test patches came close to their original colors. For the condition R12+W13 the color appearance returned to their original color in most test patches, but there are exceptions. Color of the green test patch was much far from the original color in the subjects PP and MW even with the window W5. Color of the blue test patch was not close to the original color in the subject PP. For the condition R19+W6 the color of most test patches returned in the direction of their original color. The subject PP showed a little bit different pattern from the other four subjects. For the condition R25+W0 all subjects show a similar pattern of the color appearance change. Regardless the test patches the data points fell on the horizontal axis implying that there was no yellow color nor blue color. They appeared all reddish. This is understandable. In Fig. 4-7 Chromaticity coordinates of test patches are plotted on the CIE xy chromaticity diagram. In the case of yellow illumination of the highest saturation they all lied on the spectral locus. Although we could not measure the color of test patches for the red illumination of the highest saturation we could suppose the colors also lie on the spectral locus having only red color in the sense of psychophysical color. Then the color appearance can be all reddish.

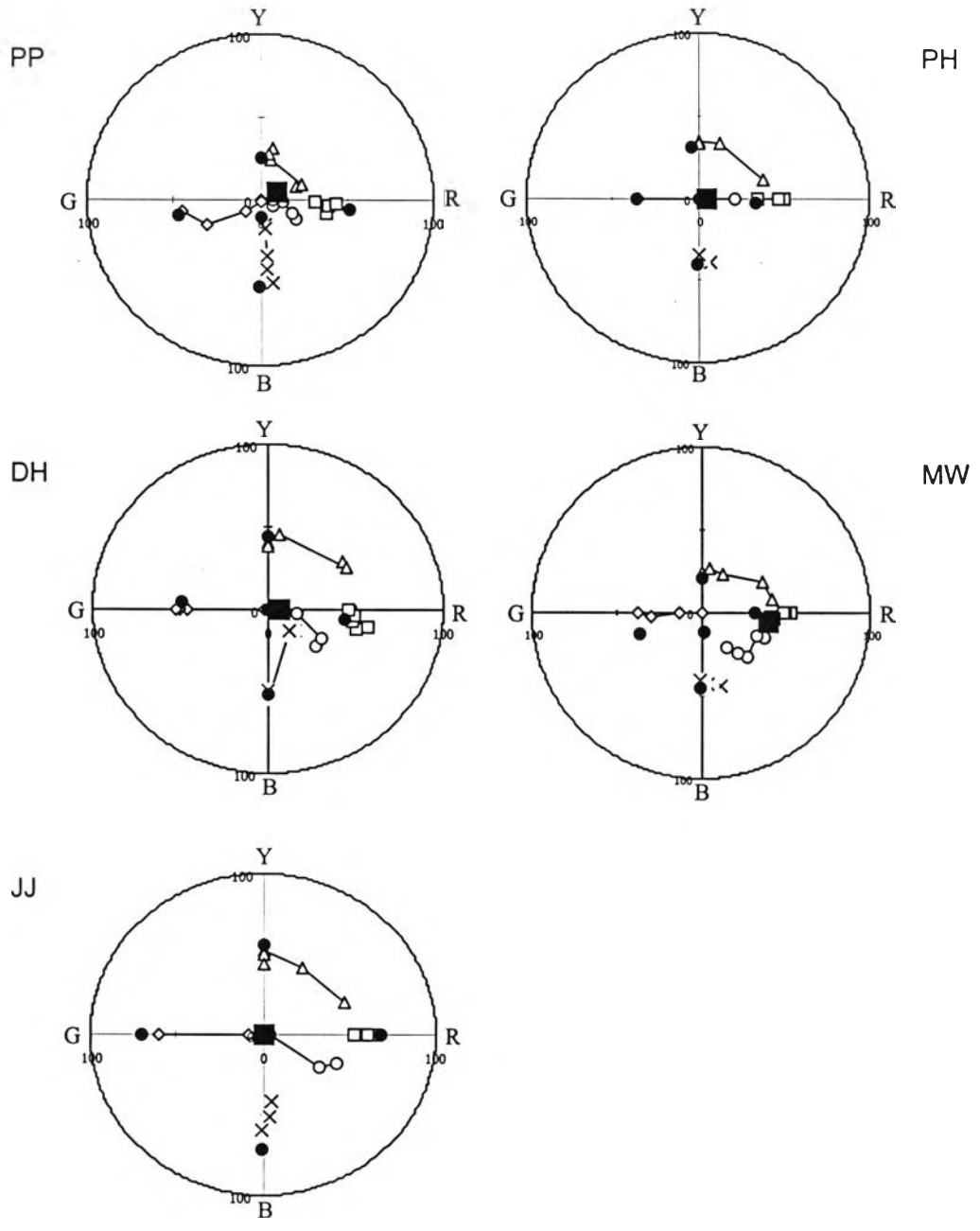

Fig. 4-6a Results for condition R5+W20. Each section corresponds to a subject.

□ , the test patch 5R5/3; △ , 5Y5/3; ◇ , 5G5/3; X , 5B5/3; ○ , N5

● , original color; ■ , color of illumination

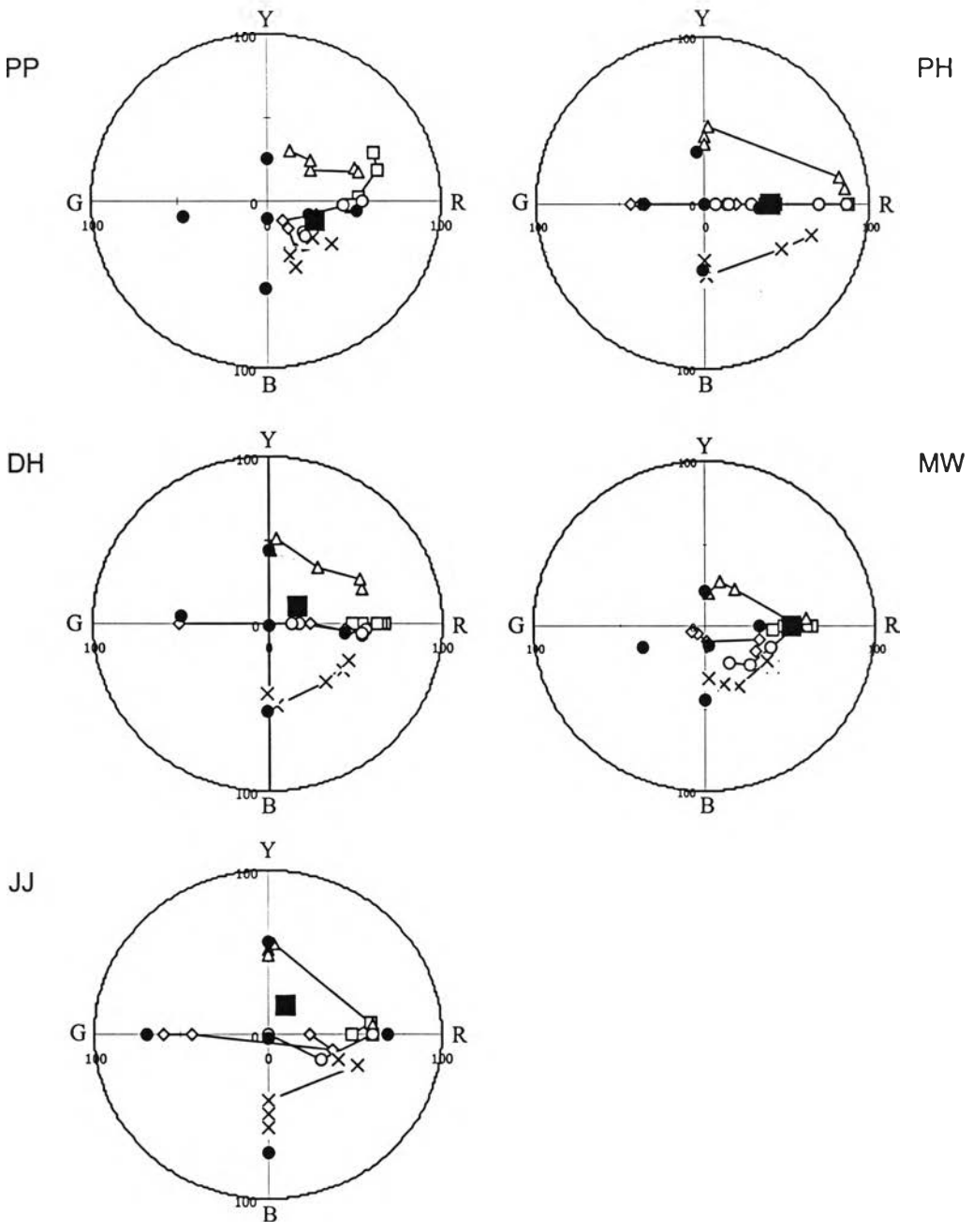

Fig. 4-6b Results for condition R12+W13. Each section corresponds to a subject.

□ , the test patch 5R5/3; △ , 5Y5/3; ◇ , 5G5/3; X , 5B5/3; ○ , N5

● , original color; ■ , color of illumination

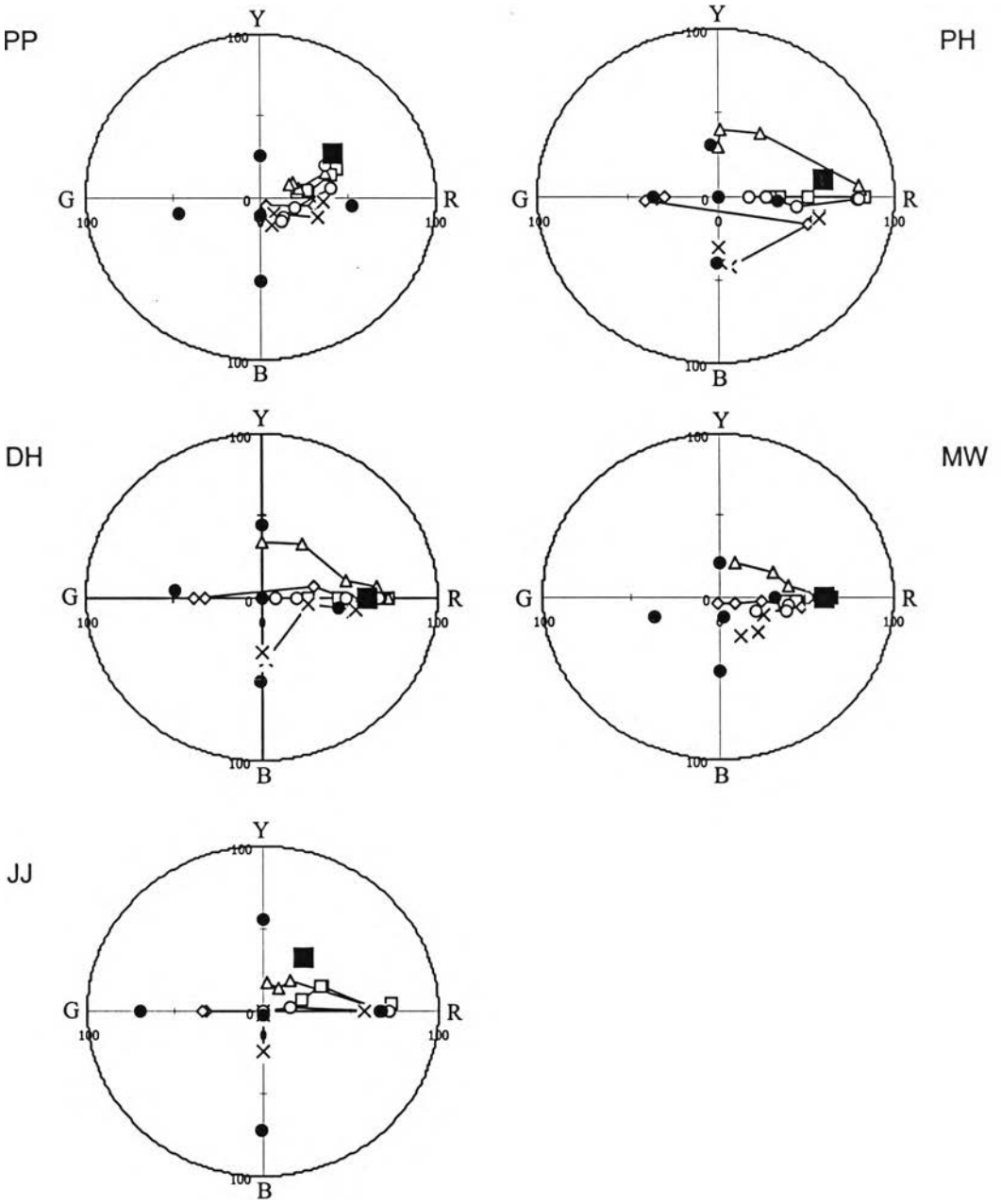

Fig. 4-6c Results for condition R19+W6. Each section corresponds to a subject.

□ , the test patch 5R5/3; △ , 5Y5/3; ◇ , 5G5/3; X , 5B5/3; ○ , N5

● , original color; ■ , color of illumination

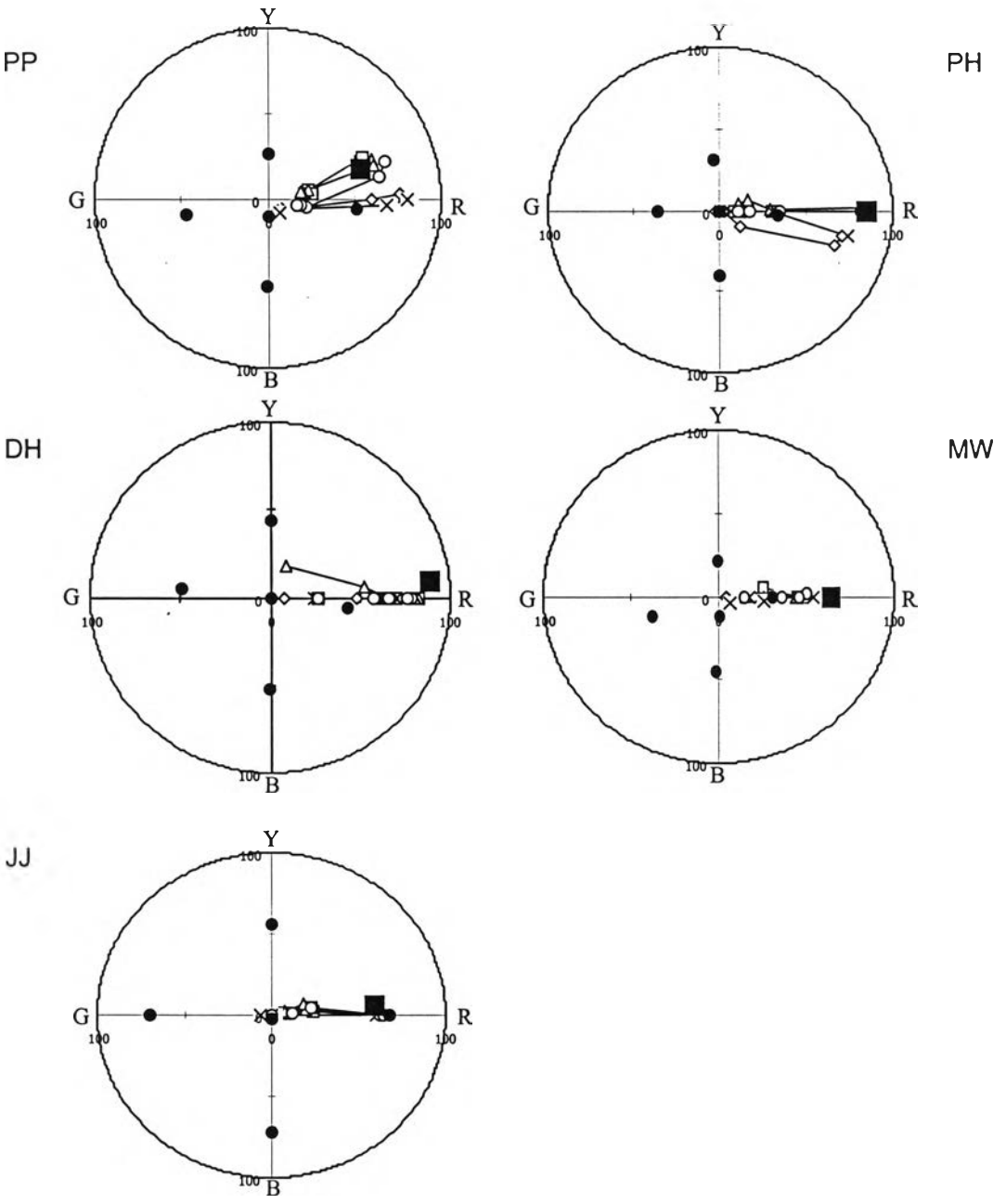

Fig. 4-6d Results for condition R25+W0. Each section corresponds to a subject.

□ , the test patch 5R5/3; △ , 5Y5/3; ◇ , 5G5/3; X , 5B5/3; ○ , N5

● , original color; ■ , color of illumination

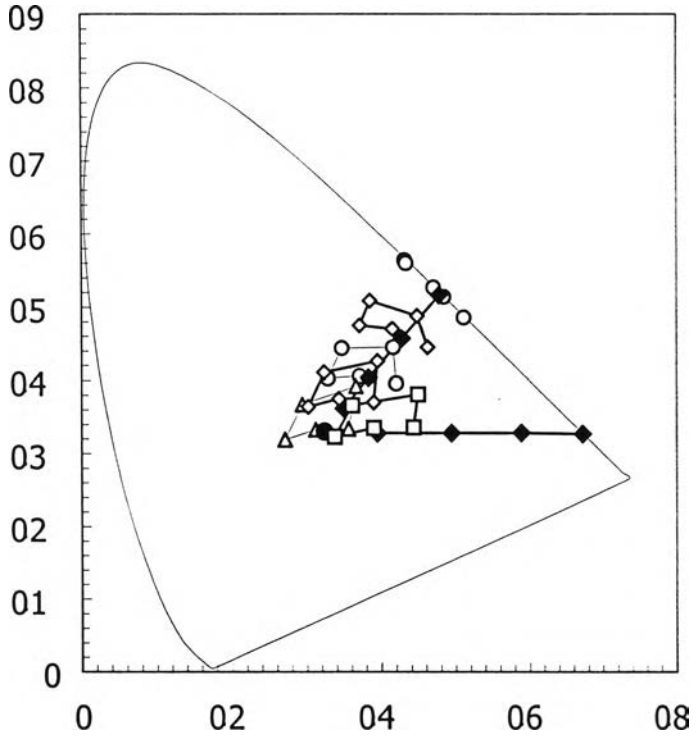

Fig. 4-7 Chromaticity coordinates of test patches are plotted on the CIE xy chromaticity diagram

The results from all five subjects and for all the saturations of yellow illumination are shown in Fig. 4-8a-d, a for Y5+W20, b for Y12+W13, c for Y19+W6 and d for Y25+W0. Sections in each figure correspond to subjects as in the case of Fig. 4-6. Different symbols represent test patches, square for 5R5/3, triangles for 5Y5/3, diamonds for 5G5/3, exes for 5B5/3 and circles for N5. Filled circles show the original color of the test patches and large filled squares show the colors of illumination.

At one glance we notice results are quite different among saturation of yellow illumination. With the illumination Y5+W20 the color appearance almost coincides with the original color for all the test patches and for all the window size. In other words the subjects perceived color of test patches as if they were placed in the illumination of daylight type if the saturation of the yellow illumination is very low. When the saturation

was increased to Y12+W13 some change occurred, particularly with the blue test patch. It appeared as green with W1 and W2 and returned to the original color for wider windows. The effect of the yellow illumination expanded to other test patches when the saturation is further increased to Y19+W6. When the window was small as W1 and W2 the color appearance of the test patches shifted upward to the yellow direction but in different degrees depending on the saturation of yellow light as expected from psychophysical color of the test patches. When the window size was enlarged the color shifted to return to their original colors. With the yellow illumination of Y25+W0 the recovery of the color appearance with the largest window W5 is rather poor in many subjects and in many test patches. Particularly the test patches of blue and gray stayed far from the original color even with W5.

But contrary to the case of red illumination of the extreme saturation the color appearance change in the case of yellow illumination of the extreme saturation is within the expectation from the result of Pontawee et al. With small windows W1 and W2 the color appearance shifted toward yellow side and with large windows W3, W4 and W5 it shifted toward the original color. Sudden change of the color appearance from W2 to W3 did not take place and the shift was rather gradual except the blue test patch with the subject JJ.

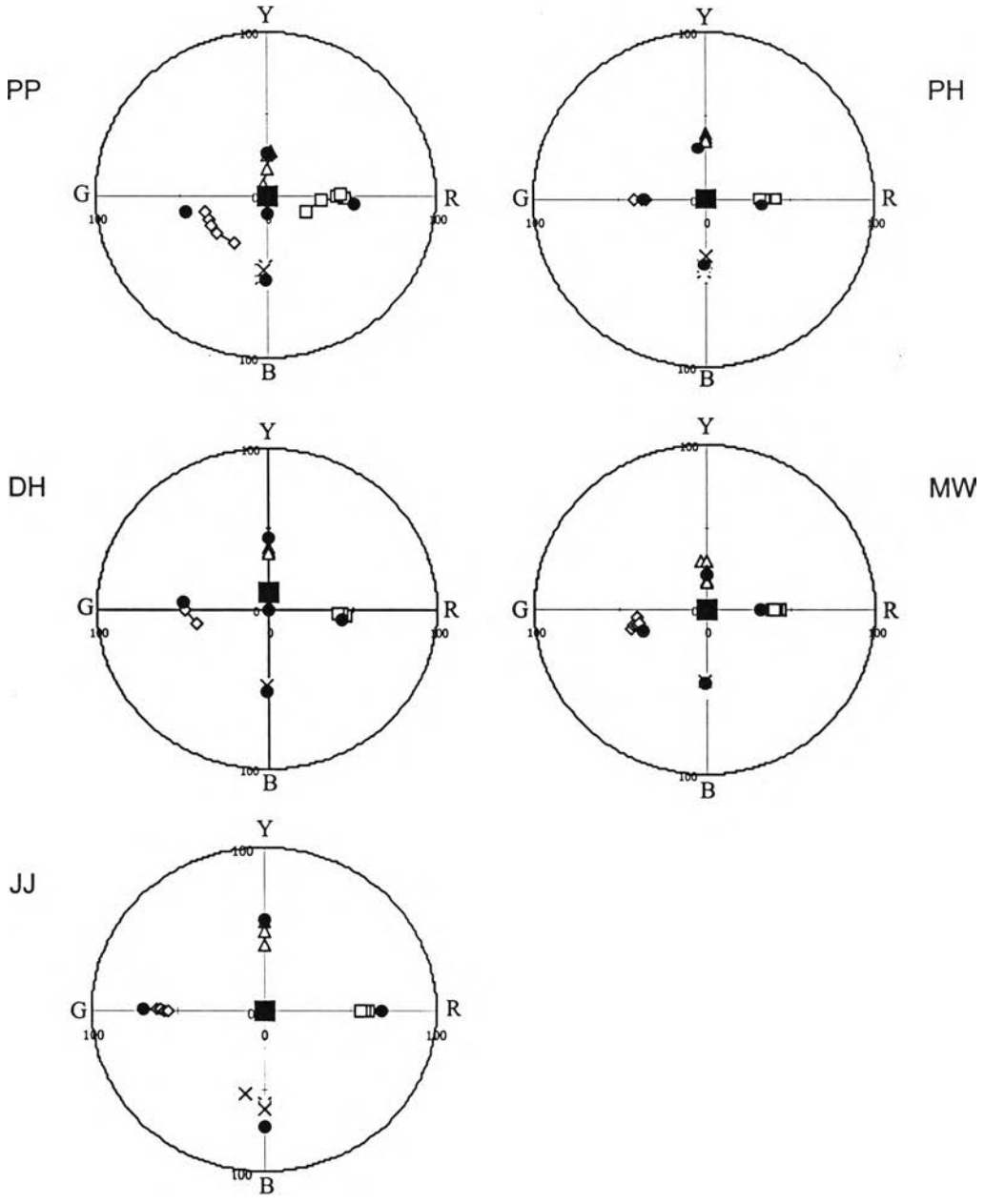

Fig. 4-8a Results for condition Y5+W20. Each section corresponds to a subject.

□ , the test patch 5R5/3; △ , 5Y5/3; ◇ , 5G5/3; X , 5B5/3; ○ , N5

● , original color; ■ , color of illumination

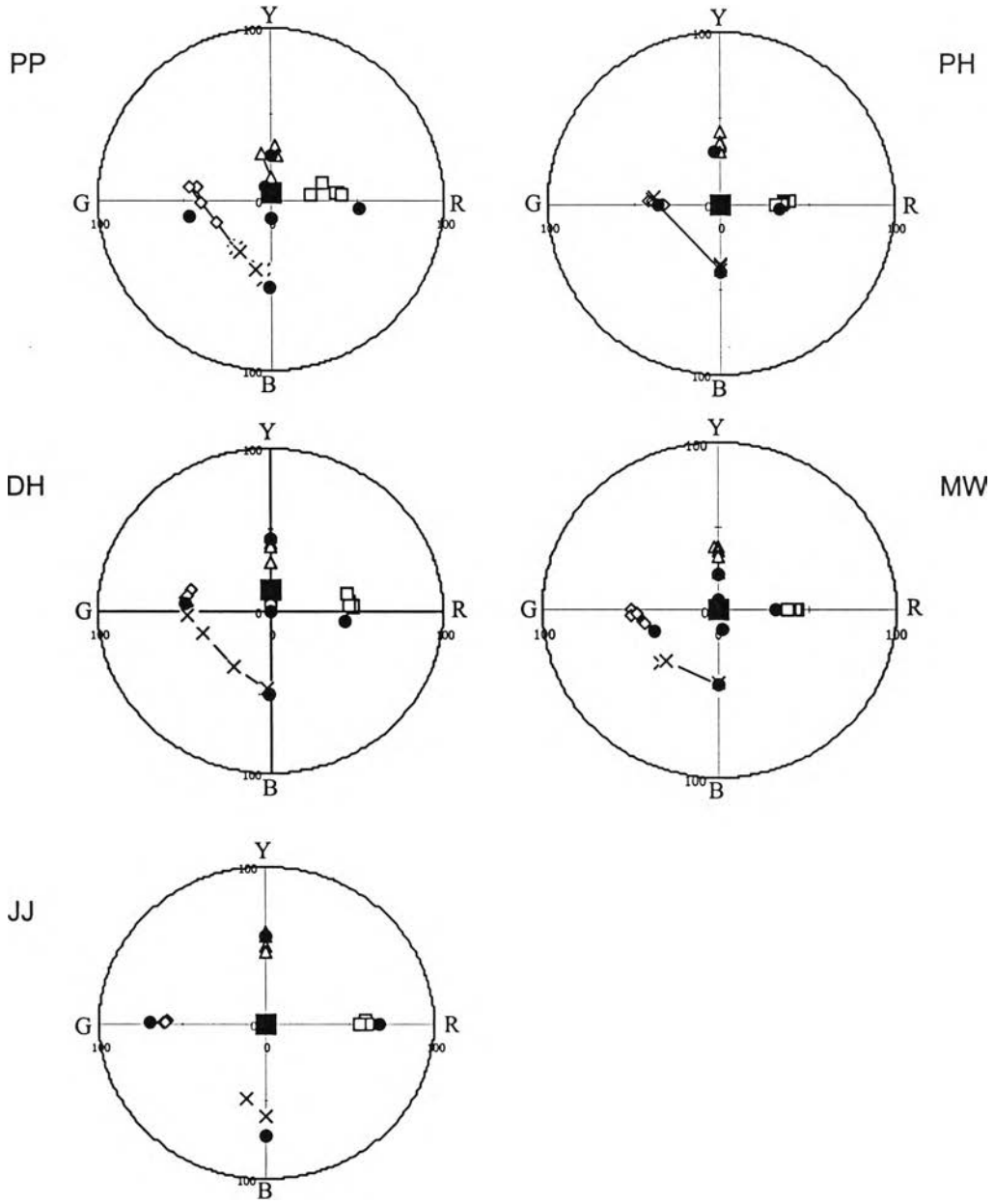

Fig. 4-8b Results for condition Y12+W13. Each section corresponds to a subject.

□ , the test patch 5R5/3; △ , 5Y5/3; ◇ , 5G5/3; X , 5B5/3; ○ , N5

● , original color; ■ , color of illumination

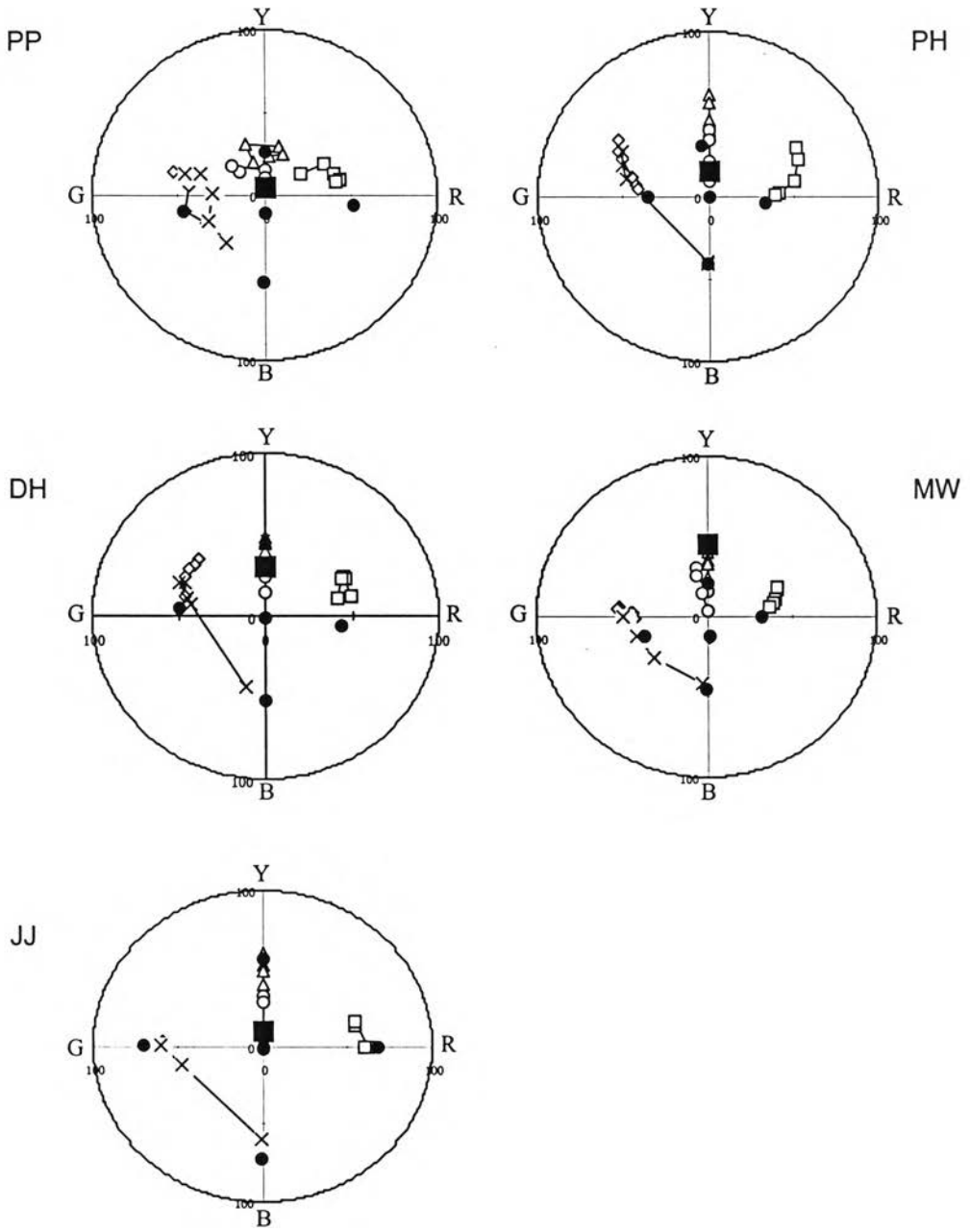

Fig. 4-8c Results for condition Y19+W6. Each section corresponds to a subject.

□ , the test patch 5R5/3; △ , 5Y5/3; ◇ , 5G5/3; X , 5B5/3; ○ , N5

● , original color ; ■ , color of illumination

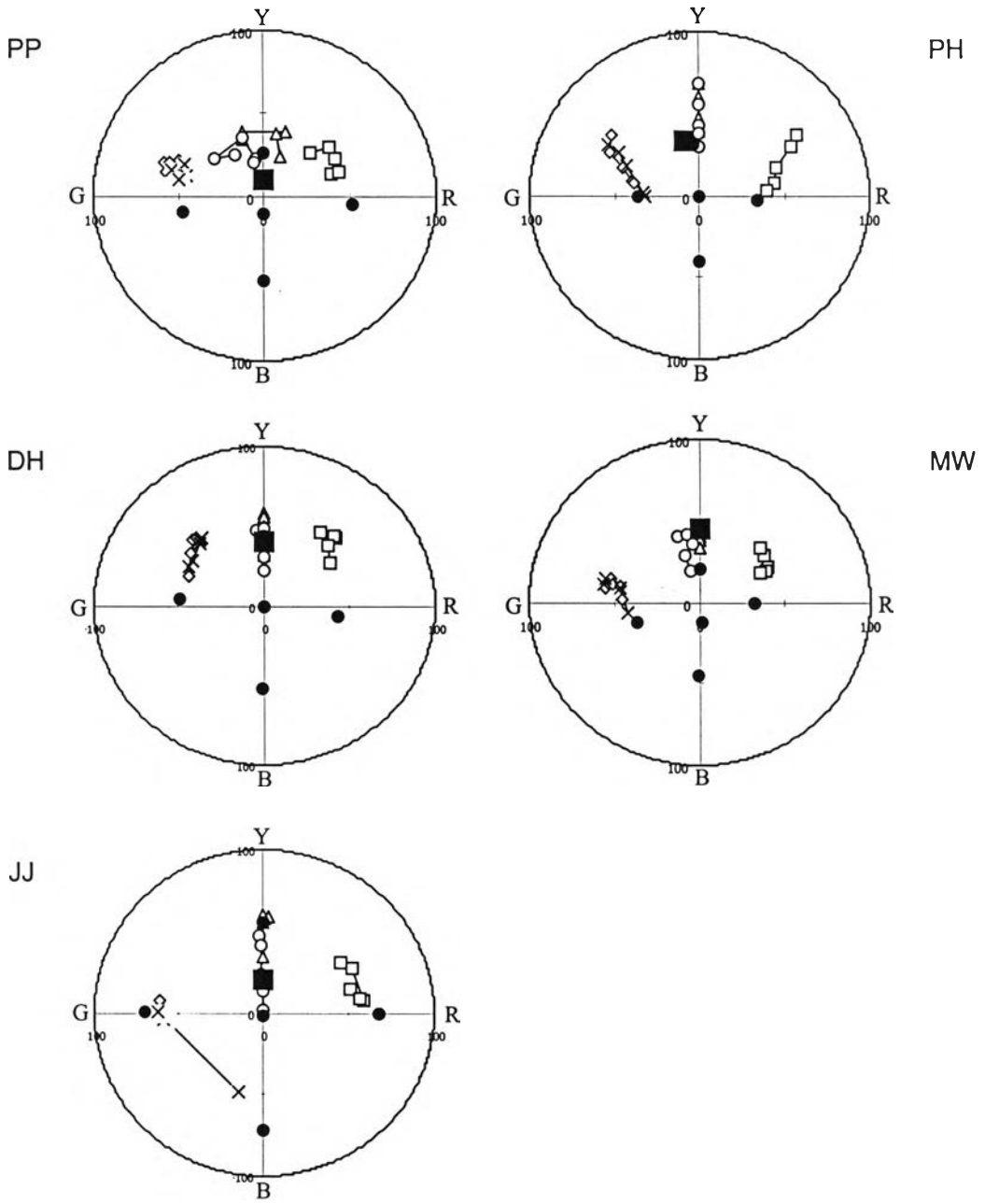

Fig. 4-8d Results for condition Y25+W0. Each section corresponds to a subject.

□ , the test patch 5R5/3; △ , 5Y5/3; ◇ , 5G5/3; X , 5B5/3; ○ , N5

● , original color; ■ , color of illumination

To see overall properties of color appearance change in test patches and for different saturation of illumination color, we took the average of the five subjects. Fig. 4-9 is the result for red illumination and Fig. 4-10 for yellow illumination. The color appearance of the illumination in the test room is shown by large filled squares. Different symbols represent test patches.

In the red illumination all the data points are drawn toward right with the window W1. The color appearance of test patches is influenced directly by the red illumination. When the window is enlarged to W5 so that the subjects could see many objects in the test room beside the test patch and could recognize the existence of the test room, the appearance return to the original color. But perfect return only occurs for the lowest saturation of the test room illumination, R5+W20. When the saturation is increased to the next step, R12+W13, the returning becomes imperfect in some test patches such as green, blue and even gray. For a further increase of the saturation the recovery becomes poorer and at the same time the appearance of yellow and blue decreases. Finally with the saturation R25+W0 no perception of yellow and blue is experienced and all the points lie on the R-G axis. Green is not perceived either.

In the yellow illumination the situation is quite different from the red illumination. Regardless the window size the color appearance in most test patches coincides with their respective original colors. Only exception is the blue test patch which appeared green with small windows. Even with large windows it appeared green for the most saturated illumination, Y25+W0. In general we may say that the color constancy holds for the yellow illumination of all the saturation investigated.

The different property between the red and yellow illumination can be more clearly demonstrated by replotting only the data of W5 in Fig. 4-9 and Fig. 4-10, which is shown in Fig. 4-11. Data of test patch N5 are not plotted. Filled circles with dotted lines are original color of test patches. Symbols correspond to the saturation of illumination, open squares to the least saturation, and open triangles, open diamonds, and open circles follow. When we connect four data points of a saturation, we can clearly see that

the connected quadrangle rapidly shrinks as the saturation of the illumination increases in the case of the red illumination, but it does not in the case of the yellow illumination. The color constancy only holds for the least saturation in the red illumination and it becomes poorer and poorer for higher saturation. For the yellow illumination the connected quadrangle remains almost same as that of the original color even the saturation is increased. The last square of the highest saturation appears different from others, but the difference is caused only by the color appearance of the blue test patch, which appeared green even with W5. The color constancy holds quite well with the yellow illumination.

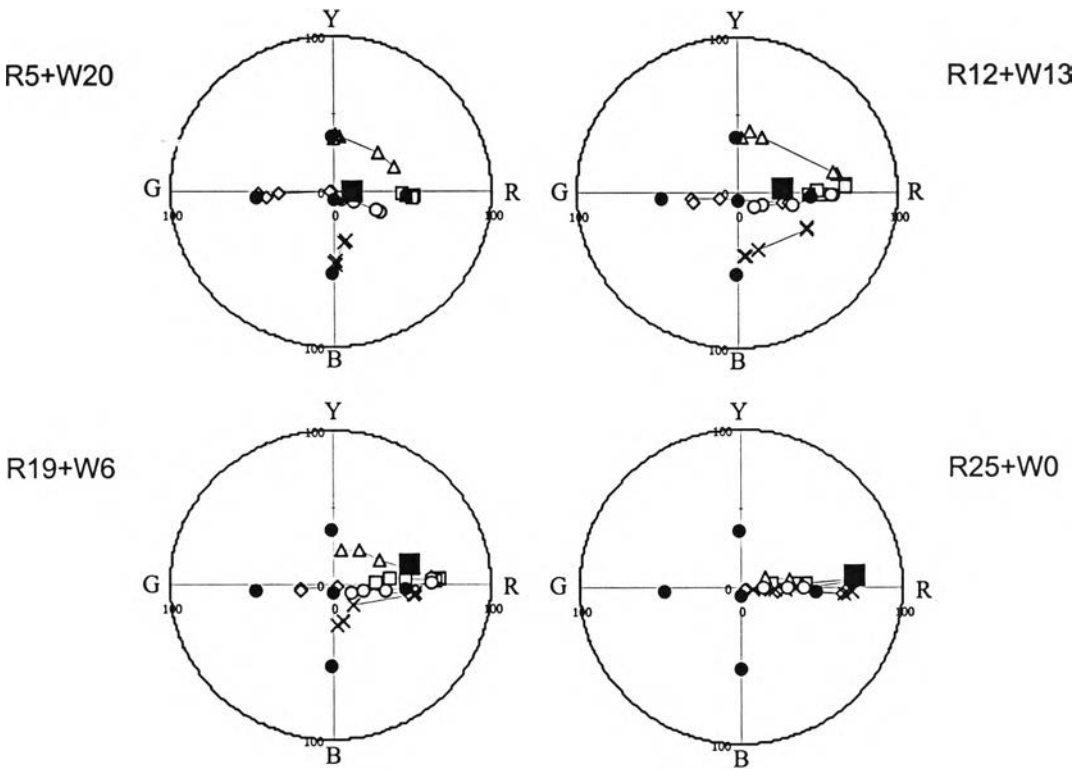

Fig. 4-9 Mean results for the red illumination and five test patches. Each section corresponds to an illumination condition.

□ , the test patch 5R5/3; △ , 5Y5/3; ◇ , 5G5/3; X , 5B5/3; ○ , N5

● , original color; ■ , color of illumination

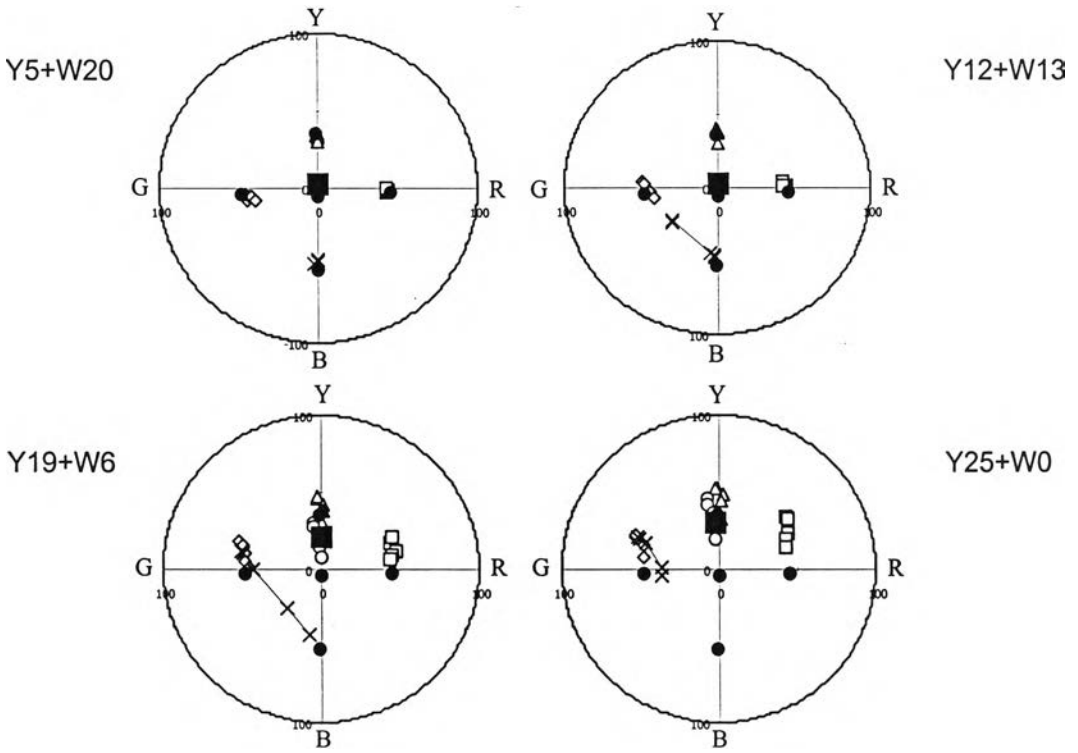

Fig. 4-10 Mean results for the yellow illumination and five test patches. Each section corresponds to an illumination condition.

□ , the test patch 5R5/3; △ , 5Y5/3; ◇ , 5G5/3; X , 5B5/3; ○ , N5

● , original color; ■ , color of illumination

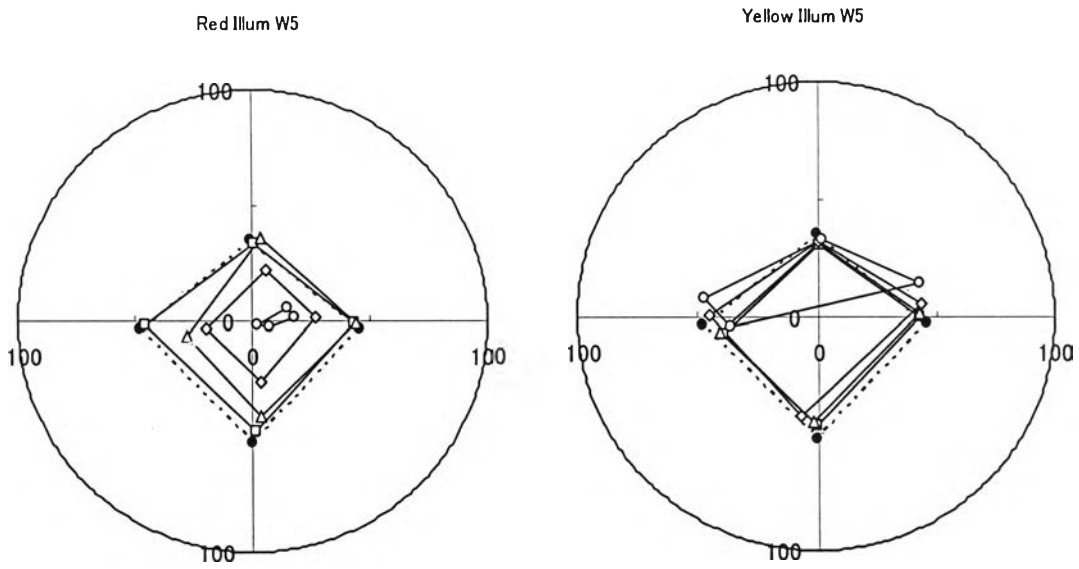

Fig. 4-11 Mean results for the red and yellow illumination and four test patches, only W5.

The results of the amounts of chromaticness, whiteness and blackness for different windows from the combination of test patch and illumination are shown in Fig. 4-12a for red illumination and in Fig. 4-12b for yellow illumination. The combination is indicated at the upper of each section; for example, 5G5/3 R5+W20 denotes the green test patch 5G5/3 observed with the condition of red illumination 5 lx combine with daylight 20 lx. Symbols represent elements: open squares for chromaticness, open circles for whiteness and filled circles for blackness. The ordinate gives the amount of each element in percentage and the abscissa the window size. In the case of the green patch observed with red illumination condition R5+W20 and R12+W13 shown in Fig. 4-12a the amounts of chromaticness were small with window 1 and window 2. But when looked at the green patch through window 3 the amounts of chormaticness increase with the amounts of whiteness and blackness decrease. On the other hand, when observed the green patch with red illumination condition R19+W6 and R25+W0 the

amounts of chromaticness were large with window 1 and window 2 and drop suddenly with window 3. The drop is replaced by both whiteness and blackness. This indicates that there was a big change in the recognition from window 2 to window 3. With the former window the subject recognized only the subject room and the test patch was a mere object belonging to the subject room. With the latter window the subject could see portions of plant leaves and other subjects beside the test patch and could clearly recognize the test room. In the case of blue patch observed with yellow illumination condition Y5+W20 and Y12+W13 the amounts of chromaticness, whiteness and blackness did not change much as shown in figure 4-12b. This because of the saturation of yellow light is low so that the subject perceived the color of illumination almost white. Results for the blue patch observed with yellow illumination condition Y19+W6 and Y25+W0 with window 1 and window 2 the amount of chromaticness were a little bit larger than with window 3.

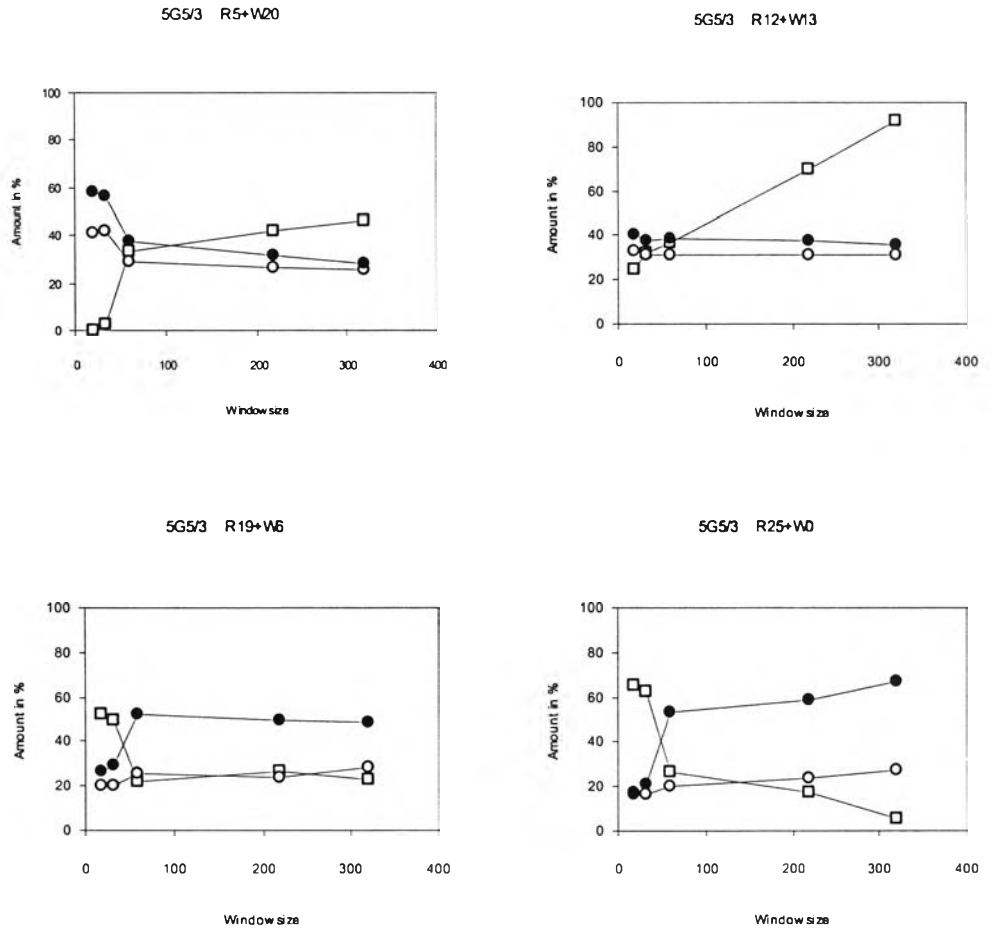

Fig. 4-12a Change of color elements for different window size. □ , chromaticness; ○ , whiteness; ● , blackness. The test patch-red illumination condition is shown at the upper of each section. Average of five subjects.

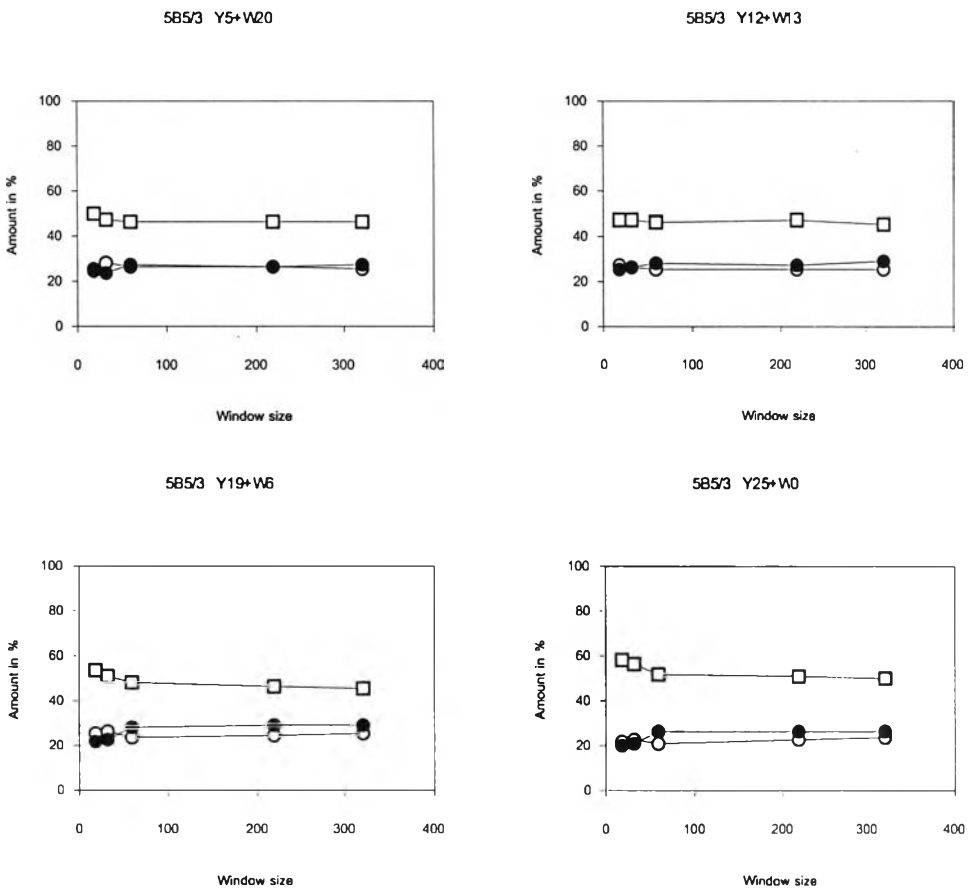

Fig. 4-12b Change of color elements for different window size. □ , chromaticness; ○ , whiteness; ● , blackness. The test patch-yellow illumination condition is shown at the upper of each section. Average of five subjects.